Phys 131 2016

Lecture 17

Fri: SPS meeting

Mon: Warm Up 7

Tues: Supp Ex 45

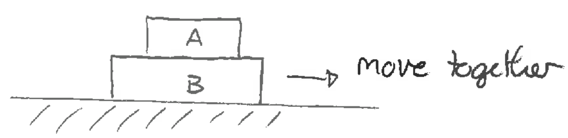
Ch 7 Conc Q 5,6,7

Ch 7 Prob 9,29

Interacting objects

Many physical situations involve two or more objects which interact and which move. Examples include:

1) stacked objects

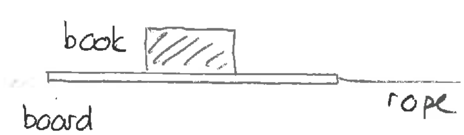


2) objects connected by ropes or cables Demo: Wikipedia Dusquesne Incline funicular

3) planets orbiting stars → search for extra solar system planets

Quiz 1

Depending on the friction between the board and book the book might slip relative to the board. We might ask

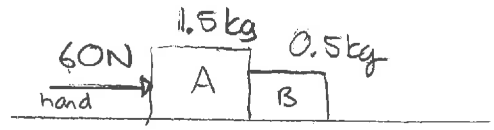


- what is the maximum force that the rope could exert so that there is no slipping?
- beyond this maximum force what would the acceleration of the board be?

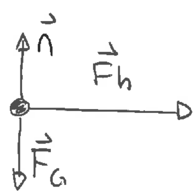
To answer these requires understanding interactions between objects.

As a generic example of the interaction between two objects consider two boxes on a frictionless horizontal surface.

Suppose that a hand pushes right on block A. The two blocks will move together with the same acceleration.



In this case considering the two blocks as a single object and applying Newton's 2nd Law to the object gives:



$$\sum F_x = m_{both}\, a_x$$

$$\Rightarrow \quad F_h = m_{both}\, a_x$$

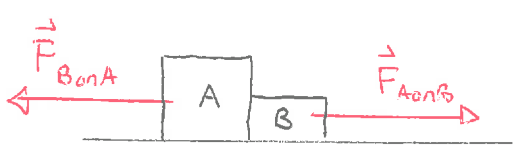
$$\Rightarrow \quad 60\text{N} = 2.0\text{kg}\; a_x \quad \Rightarrow \quad a_x = 30\,\text{m/s}^2$$

But the hand actually acts on box A. Thus we can ask

1) what force acts on box B?

2) If box B were absent, the acceleration of box A would be $40\,\text{m/s}^2$. What other force acts on box A so as to reduce its acceleration when box B is present?

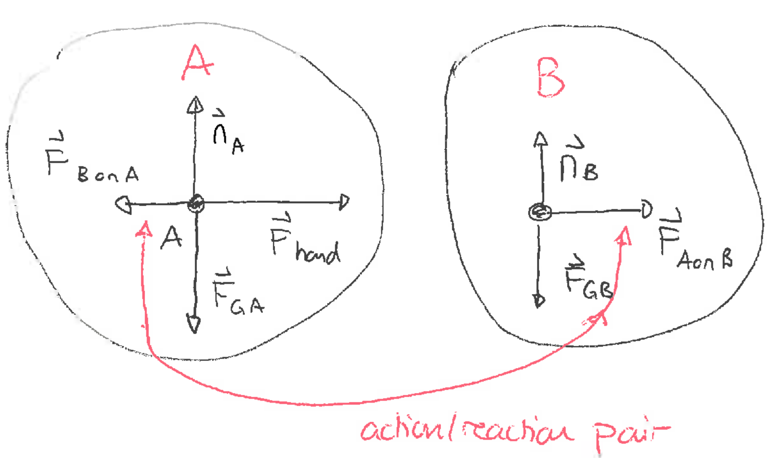
Since the boxes are in contact, we expect that they each exert contact forces on each other. This pair of forces is called an <u>action/reaction pair</u>.



The details are:

1) Box A exerts a force on box B. This force exerted on box B is denoted $\vec{F}_{A\,on\,B}$ and is only included on the FBD for B.

2) Box B exerts a force on box A denoted $\vec{F}_{B\,on\,A}$



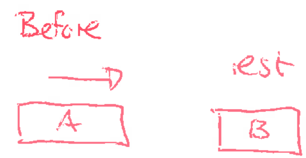
Such action / reaction pairs:

1) always refer to two objects only
2) never appear on the same FBD - each force only appears on the FBD of the object on which it acts.

Quizz

These evidently occur throughout classical physics.

Demo: - Carts with magnets on a track
- Collide carts + observe



We can see that during the collision:

- each cart accelerates
- the net force on each cart is non-zero

This allows us to begin to assess forces exerted by one cart on another

	Cart A	Cart B
earlier velocity	$\longrightarrow$ $\vec{v}_i$	$\vec{v}_i = 0$
later velocity	$\rightarrow$ $\vec{v}_f$	$\longrightarrow$ $\vec{v}_f$
change in velocity $\Delta\vec{v} = \vec{v}_f - \vec{v}_i$	$\longleftarrow$ $\Delta\vec{v}$	$\longrightarrow$ $\Delta\vec{v}$
acceleration	$\vec{a}$ $\longleftarrow$	$\vec{a}$ $\longrightarrow$
net force	$\longleftarrow$ $\vec{F}_{net\ A}$	$\longrightarrow$ $\vec{F}_{net\ on\ B}$

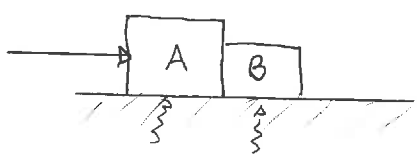
The net force on A can only result from a force that B exerts and vice-versa. This is another example of an action / reaction pair. In general one always finds:

$\boxed{\text{If object A exerts a force on object B, then object B exerts a force on object A}}$

In many situations, such as that of the two boxes, we don't really need to consider the forces between the objects in order to understand their motion. But for these boxes this is possible because

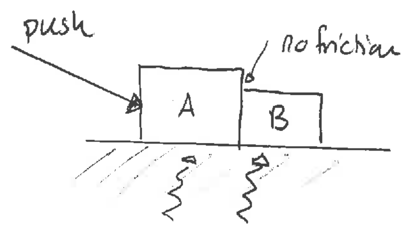
1) both objects have the same motion (velocity + acceleration)
2) we are not asking about the forces exerted on object A
   (a consideration if object A could only withstand some maximum force)

3) the force situation is relatively simple. More complicated examples would be:



different coefficients of friction

or



same friction

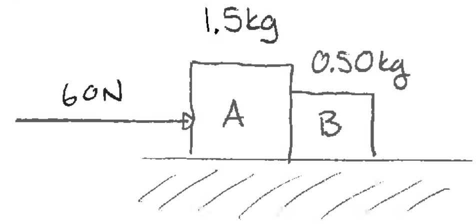
friction on A depends on push, but not B. How to combine?

We need a general rule for the interactions and forces between such pairs of objects.

Forces between interacting objects

We can use the previous example to suggest a general relationship between forces between pairs of objects.

Example: Consider two boxes on a frictionless horizontal surface. Determine



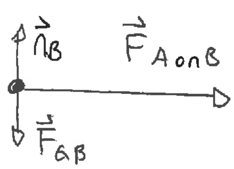
a) the force exerted by A on B

b) the force " " B on A.

Answer: By considering A and B as a single object, we found that

- the acceleration of A is $\vec{a}_A = 30 m/s^2 \rightarrow$
- the acceleration of B is $\vec{a}_B = 30 m/s^2 \rightarrow$

* Now apply Newton's 2^{nd} Law to B.



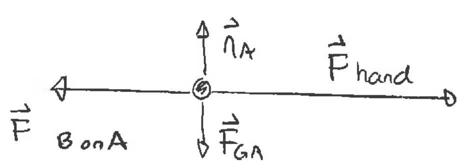
$$\sum_{\text{forces on B}} F_x = m_B a_{Bx}$$

$$\Rightarrow F_{A on B} = 0.50kg\, a_{Bx} = 0.50kg \times 30 m/s^2$$

$$\Rightarrow \vec{F}_{A on B} = 15N \text{ to right}$$

* Apply Newton's 2^{nd} Law to A:

$$\sum_{\text{on A}} F_x = m_A a_{Ax}$$



$$\Rightarrow F_{hand} - F_{B on A} = 1.5kg \times 30 m/s^2$$

$$\Rightarrow 60N - F_{B on A} = 45N$$

$$\Rightarrow \vec{F}_{B on A} = 15N \text{ to left.}$$

What we have seen here is an example of Newton's Third Law

If object A exerts a force on object B then

1) object B exerts a force on object A

2) the two forces have the same magnitudes but opposite directions